



# MAGNETIC EXCHANGE INTERACTION IN COBALT SAMARIUM THIN FILMS FOR HIGH DENSITY MAGNETIC RECORDING MEDIA

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## ABSTRACT

The effect of samarium content on magnetic interaction intensity of cobalt samarium alloys in the form of thin films deposited on silicon (100) substrates has been studied. These films were fabricated using dc magnetron sputtering technique. It was found that the intensity of magnetic interaction between grains in the films was reduced as samarium content increased. It was also showed that the coercivity of the films increases and reaches a maximum value at around 19 - 22 atomic % samarium, followed by a decrease with further increase in samarium concentration. The hysteresis loop squareness of the samples decreases as samarium content increases. Moreover, the degree of crystalline of the films decreases as samarium concentration is increased. Thus the increase of coercivity of the films in this range is also discussed.

**Keywords:** interaction intensity, coercivity, loop squareness, magnetic thin films.

## INTRODUCTION

Alloys of cobalt samarium in the form of thin films have been the subject of intense research nowadays due to their high coercivity values [1]. One of the most potential applications of such alloys is for high density magnetic recording media. According to Murdock *et al.*, high-density magnetic recording media require a material consisting of small and magnetically isolated grains of about 10 nm or below [2]. In order to fulfill these requirements, it is necessary to have a material with controlled microstructure. Controlling the microstructure of the growing films of cobalt samarium alloys is believed to be the best way to improve the magnetic properties. This can be achieved by the introduction of under layer materials [3] and by heating substrate temperature or post-annealing of as-deposited films. The alloys of cobalt samarium in the form of thin films exhibiting large coercivity values were explored by Gronou *et al.* [4]. They reported that the films were fabricated using flash evaporation onto glass substrates and generating large coercivity value. Some recording experiments using thin film of cobalt samarium have been investigated, for example, by Velu *et al.* [5] and Velu *et al.* [6]. The growth characteristics of cobalt samarium alloys including the concentration range [7], the epitaxial relation between the films and under layer materials [8, 9], interaction effects [10, 11], and the magnetic switching volume [12] suggested that improved magnetic properties of the films could be obtained by adjusting optimum deposition conditions.

There are some approaches at controlling the microstructure of growing films, namely the isolation of the magnetic grains from their neighbors in thin film media by alloying ferromagnetic element with non magnetic element such as samarium. Isolating the magnetic grains of growing films could reduce interaction intensity among them, and resulting higher coercivity value of growing films. The coercivity and loop squareness of the films are governed by intensity of

interactions between neighboring grains, e.g. as observed in cobalt-phosphorus films [13]. Moreover, the magnetic grain size in the growing film is one of the important factors to control the magnetic properties of thin films [14]. This article aims to report the interaction intensity in cobalt samarium thin films based on the film composition.

## MATERIALS AND METHODS

Cobalt samarium thin films were grown on Si (100) substrates using dc magnetron sputtering technique. A series of sample were prepared under the same condition. In order to obtain films with different samarium content, then the power of cobalt magnetron source were kept constant namely 100 watts, while the magnetron power for samarium was varied from 10 to 50 watts. The pressure inside the sputtering chamber prior to deposition was  $5 \times 10^{-8}$  mbar, while the pressure chamber during the film fabrication was  $3 \times 10^{-3}$  mbar.

The film microstructures were examined by transmission electron microscope (TEM). Magnetic properties were measured using an alternating gradient force magnetometer (AGFM). The intensity of magnetic interaction between magnetic grains was determined from calculation and analysis of dc demagnetization curve ( $M_{DCD}$ ) and isothermal magnetization ( $M_{IRM}$ ).

## RESULTS AND DISCUSSIONS

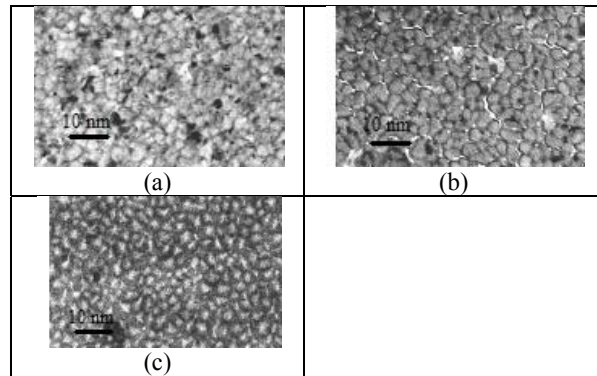
Figure-1 shows plane view TEM micro-graphs of cobalt samarium thin films at different compositions namely  $\text{Co}_{90}\text{Sm}_{10}$ ,  $\text{Co}_{80}\text{Sm}_{20}$  and  $\text{Co}_{62}\text{Sm}_{38}$ . It is clear that the films exhibit a wide range of microstructural features such as grain size and shape which depend on the samarium content, which in turn, significantly affects their magnetic properties. The film with a samarium concentration of 10 atomic % exhibits dark contrast with irregular shapes of grains as depicted in Figure-1(a), and the microstructure the film shows small physical voids or density at the grain boundaries. This film shows different



grain morphology from the film with samarium concentration of 20 atomic % as shown in Figure-1(b).

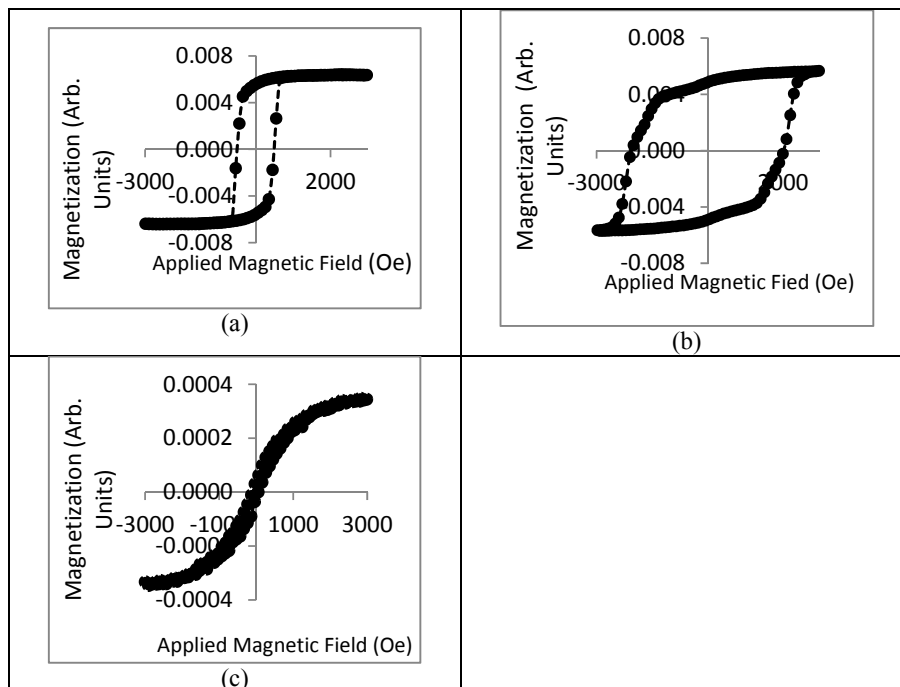
The microstructure of this sample has more rounded and uniform grains than that of  $\text{Co}_{90}\text{Sm}_{10}$ . The average grain size of the film increases from about 2 nm to 4 nm. Moreover, the  $\text{Co}_{80}\text{Sm}_{20}$  film shows grains well separated from their neighbors with wide voided boundaries that are not observed in  $\text{Co}_{90}\text{Sm}_{10}$ . This effect is possibly related to the increase in coercivity with increasing samarium concentration. This suggestion is supported by the reduction of remanent magnetization values, resulting less inter-granular exchange interaction between grains. It is well known that the grain size is one of the critical factors to control the magnetic properties of thin films [14]. Therefore, it can be assumed that in this concentration (20 atomic % of samarium) the magnetic grain size is optimized for a higher coercivity value.

The  $\text{Co}_{66}\text{Sm}_{34}$  film shows different grain morphology from the films with lower samarium concentrations as shown in Figure-1(c). The grains of this film are more cubical and amorphous. The decrease in the coercivity in the films containing more than 20 atomic % samarium as shown in Figure-2, which is associated with a corresponding greater volume fraction of the amorphous phase.



**Figure-1.** Plane view TEM micrographs of cobalt samarium thin films for (a)  $\text{Co}_{90}\text{Sm}_{10}$  (b)  $\text{Co}_{80}\text{Sm}_{20}$  and (c)  $\text{Co}_{62}\text{Sm}_{38}$ .

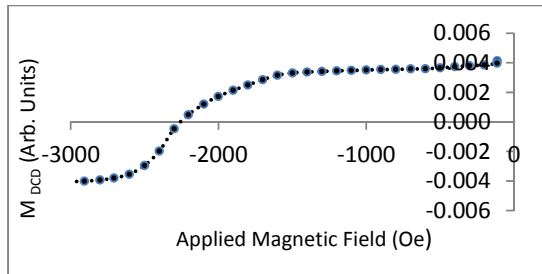
Figure-2 shows the effect of samarium concentration on the magnetic properties namely coercivity of the films. The cobalt samarium films deposited at lower samarium concentration showed lower coercivity and higher loop squareness shown in Figure-2(a). The coercivity of the films increased rapidly with increasing samarium concentration and was maximized at 20% of samarium as indicated in Figure-2(b). For a concentration of samarium that is greater than 20 at %, the grain size continues to decrease as shown in Figure-2c. This result is supported by the selected area diffraction (SAD) pattern where the diffraction rings become broader, suggesting that the degree of crystalline decreases as samarium concentration is increased [15, 16].



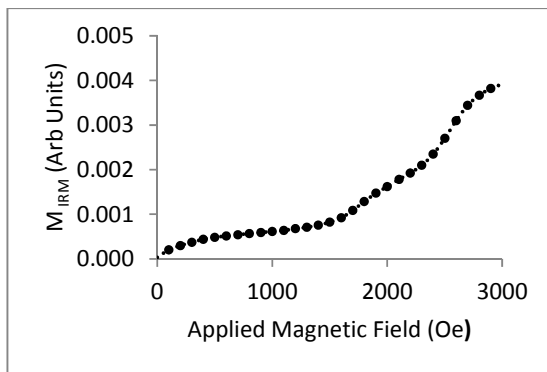
**Figure-2.** Hysteresis loop of cobalt samarium thin films for (a)  $\text{Co}_{90}\text{Sm}_{10}$  (b)  $\text{Co}_{80}\text{Sm}_{20}$  and (c)  $\text{Co}_{62}\text{Sm}_{38}$ .



Figure-3 (a) and (b) show examples of typical demagnetizing remanent magnetization ( $M_{DCD}$ ) and isothermal remanent magnetization ( $M_{IRM}$ ) curves respectively measured as a function of applied magnetic field (Oe) using alternating gradient force magnetometer (AGFM) for a  $\text{Co}_{80}\text{Sm}_{20}$  alloy film.



(a)

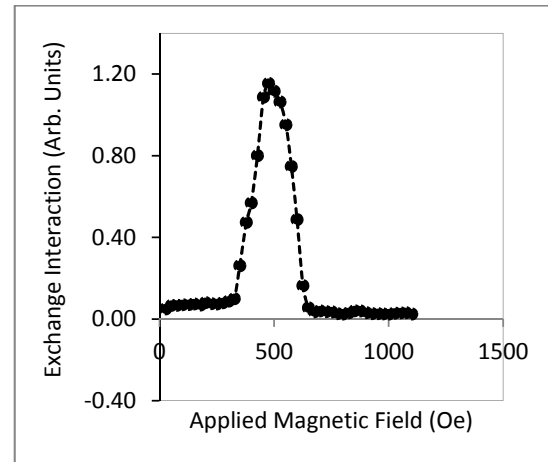


(b)

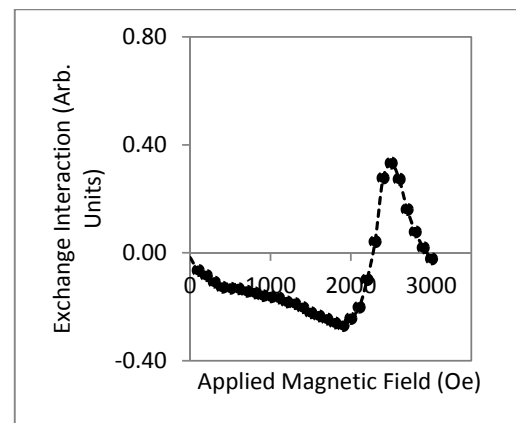
**Figure-3.** Remanent magnetization as a function of applied field for  $\text{Co}_{80}\text{Sm}_{20}$ , (a) demagnetizing remanent magnetization ( $M_{DCD}$  or  $M_d$ ) and (b) isothermal remanent magnetization ( $M_{IRM}$  or  $M_r$ ).

The value of demagnetizing remanent magnetization ( $M_{DCD}$ ) is obtained by saturating the sample using applied field in the negative direction. The demagnetizing remanent magnetization is recorded as a function of applied magnetic field (Oe) in positive direction. The process of recording ( $M_{DCD}$ ) value ends until saturation is achieved. In order to obtain the isothermal remanent magnetization values ( $M_{IRM}$ ) then the film has to be AC demagnetized and then remanent values of the film are recorded as a function increasing applied magnetic field (Oe) until the saturation condition. The difference between the normalized demagnetizing remanent magnetization and normalized isothermal remanent magnetization values shows the nature of interactions in thin films [13].

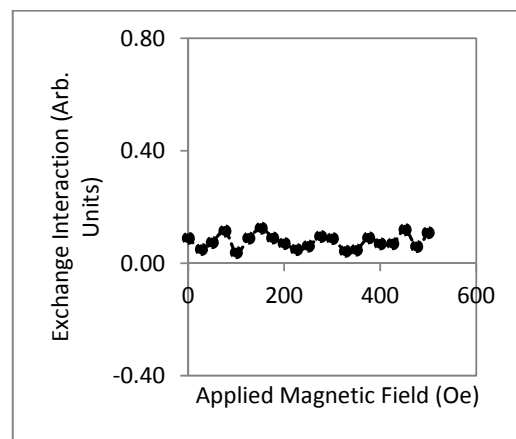
The value of magnetic exchange interaction between neighboring grains in cobalt samarium films as a function of samarium content was obtained from the  $M_{DCD}$  and  $M_{IRM}$  data shown in Figure-3. Figure-4 shows the nature interaction between grains in cobalt samarium films.



(a)



(b)



(c)

**Figure-4.** Exchange interaction curves calculated from  $M_{DCD}$  and  $M_{IRM}$  data shown in Figure-3 for (a)  $\text{Co}_{90}\text{Sm}_{10}$  (b)  $\text{Co}_{80}\text{Sm}_{20}$  and (c)  $\text{Co}_{62}\text{Sm}_{38}$ .

Plot of exchange interaction or intensity interaction for the three different film compositions is shown in Figure-4. The inter-granular exchange interaction can be qualitatively estimated by the  $\delta M$  method [13]. As seen from the figure above, that



increasing samarium content causes the exchange interaction value to decrease, indicating decreasing of intergranular exchange interaction and also suggests that intergranular exchange coupling is much larger than any magneto static interaction between the grains of the films. This finding is agreed well with previous investigator<sup>[16]</sup>. Lower values of coercivity for films with higher samarium content could be due to the decrease of intergranular exchange coupling. The degree of crystalline of the films is also decrease as samarium content increase namely above 20 atomic % of samarium. This causes the coercivity of the films to decreases.

## CONCLUSIONS

The values of exchange interaction show positive values which mean that intergranular exchange coupling is stronger than magneto static interaction between the grains. Increasing the samarium content of the films, the positive maximum exchange interaction value decreases, indicating decreasing of intergranular exchange interaction. For a film with samarium content greater than 20%, the exchange interaction value is very low compared to that for films with lower samarium concentration. This phenomenon is believed to cause the coercivity of the film decreases.

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